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Coronary artery bypass grafting via median sternotomy or lateral minithoracotomy ☆

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Abstract

Objectives: In order to evaluate the benefit provided through less invasive surgical techniques for the treatment of multivessel coronary artery disease, a prospective clinical trial was started. **Methods**: Group 1 included 53 patients (38 males, 15 females, age 51–79 years, mean 62.8 ± 6.1 years) receiving conventional bypass surgery, group 2 included 69 patients (59 male, 10 female, age 43–82 years, mean 61.9 ± 8.6 years) receiving less invasive surgical procedure including minithoracotomy in combination with cardiopulmonary bypass. **Results**: No perioperative death occurred in the whole series of patients. Time of operation was 267 ± 61 min in group 2 and 162.9 ± 53.6 min in group 1. Intensive Care Unit stay was 1 day for both groups and Hospitalization 6.9 ± 6.0 for group 1 and 7.5 ± 2.6 days for group 2. Perioperative bleeding was less in group 2 ($P > 0.01$). Back and chest pain assessment on postoperative day 3 showed less pain in group 2 ($P < 0.05$). Three-month follow-up revealed ischemia in stress electrocardiogram in two patients (3.8%) in group 1 and in 2 patients (2.9%) in group 2. Coronary angiograms confirmed the stress ECG findings. There was one (1.4%) redo operation in group 2 and two (3.8%) in group 1. **Conclusions**: Both techniques are equal efficient. Even though time of operation is longer in patients receiving less invasive procedure, intensive care unit stay and hospitalization is exactly as long. Patients receiving minimally invasive surgery bleed less and have less pain early postoperatively.

Keywords: Multivessel coronary artery disease; Minimally invasive coronary artery bypass surgery; Pain assessment; Minithoracotomy; Median sternotomy

1. Introduction

The new trend in surgery, to reduce perioperative trauma also invaded cardiac surgery, avoiding median sternotomy [1], or cardiopulmonary bypass or even both [2,3]. In the Netherlands a surgical group proposed mechanical stabilization for the performance of coronary anastomoses in all areas of the heart avoiding cardiopulmonary bypass (CPB) over median sternotomy [4]. After having gained experience with the Port-Access™ system [5] the Dresden group developed a new approach performing coronary bypass surgery even in complex cases of CAD avoiding median sternotomy with the help of CPB [6]. If median sternotomy is avoided in coronary artery bypass surgery, perioperative sternotomy related morbidity [7–9] should be reduced. The proposed technique (DT) enables in its mature version CPB institution without dissection of the groin, being related to wound healing complications, and – what is more important – avoiding femoral cannulation of the arterial system, being related to severe intraoperative complications as retrograde aortic dissections [10]. This surgical method was successfully performed and found great acceptance on behave of the patients. The extended length of operation, led this surgical group to start a prospective clinical trial, comparing this novel technique with the conventional coronary artery bypass surgery, in order to define the benefit provided.

2. Patients and methods

Heavy calcification of the ascending aorta was a serious exclusion criterion for both groups. Therefore all patients underwent preoperative transthoracic echocardiography. Impaired left ventricular ejection fraction, less than 30% and a body mass index of more than 30 were further exclusion criteria. All patients were operated in mild hypothermia using the same antegrade crystalloid cardioplegic solution. Anesthesia and anticoagulation monitoring used were the same for both groups.

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2.1. Conventional technique (group 1)

The age of the 53 patients evaluated for conventional surgery, ranged from 51 to 79 years (mean 62.8 ± 6.1 years), 38 were male (71.7%) and 15 were female (28.2%).

Twelve (22.6%) patients suffered from coronary artery single-vessel disease, but five (9.4%) among them were referred for double-bypass surgery as diagonal branches of the LAD were involved with stenotic lesions as well. In the same group 30 (56.6%) patients had a coronary artery double-vessel and further 11 (20.8%) a triple-vessel disease. The pattern of coronary lesions is listed on Table 1. Twenty-seven (50.9%) patients had a previous myocardial infarction and two (3.8%) of them claimed to have unstable angina. Seven (13.2%) patients had previous percutaneous transluminal angioplasties. The preoperative left ventricle ejection fraction (LVEF) ranged from 42 to 92% (mean 66.4 ± 15.6%). Two (3.8%) patients were in CCS stage 1, 20 (37.7%) patients in CCS stage 2, 27 (51%) in CCS stage 3, and four (7.5%) patients were in CCS stage 4. Ten (19%) patients were in New York Heart Association (NYHA) class I, 20 (37.7 %) patients in class II, 22 (41.5%) patients in class 3, and 1 (1.8%) patients in class IV. Two patients suffered from chronic atrial fibrillation and the values of Hk and Hb were 43.0 ± 3.2% (mean ± SEM) and 8.9 ± 0.7 mmol/l (median ± SEM), respectively.

After introduction of anesthesia, the patient was placed in supine position. A median sternotomy was performed and a conventional LIMA take down retractor was used to harvest the LIMA as a pedicle using diathermy and LIMA liga clips from the 1st to the 6th rib. The pericardium was opened longitudinally and after cannulation of the ascending aorta and of the right atrium, CPB was started. The aorta was clamped and after introduction of cardioplegia coronary anastomoses were performed in mild hypothermia (32°C). Antegrade deairing was performed, the aortic clamp was removed and the proximal anastomoses were performed, if necessary, using a side biting clamp. The patient was weaned from CPB, the cannulas were removed and the pericardium was always closed. One drain was left in the pleural, one in the pericardial cavity, and one in the mediastinum. Sternum was always closed with eight steel wires and the wound was closed in layers.

2.2. Dresden technique (group 2)

Sixty-nine patients with CAD were evaluated for DT surgery. Age ranged from 43 to 82 years (mean 61.9 ± 8.6 years), 59 were male (85.5%) and 10 were female (14.5%). Twenty-six patients (37.7%) suffered from coronary artery single-vessel disease, but 18 (26.1%) patients among them were referred for double-bypass surgery as diagonal branches of the LAD were involved with stenotic lesions as well. In the same group 30 (43.5%) patients had a coronary artery double-vessel and further 13 (18.8%) a triple-vessel disease. The pattern of coronary lesions is listed on Table 1. Forty-three (62.3%) patients had a previous myocardial infarction and two (2.9%) of them claimed to have unstable angina. Twenty (28.9%) patients had previous percutaneous transluminal angioplasties. The preoperative left ventricle ejection fraction (LVEF) ranged from 40 to 90% (mean 66.8 ± 12.5%). Clinical classification revealed that 10 (14.4%) patients were in Canadian Cardiovascular Society (CCS) stage 1, 34 (49.3%) patients in CCS stage 2, 23 (33.3%) in CCS stage 3, and 2 (2.9%) patients were in CCS stage 4. Twenty-seven (39.1%) patients were in NYHA class I, 32 (46.4%) patients in class II and 10 (14.5%) patients in class III. Five patients (5.8%) suffered from chronic atrial fibrillation and the values of hematokrit (Hk) and hemoglobin (Hb) were 42.7 ± 5.4% (mean ± SEM) and 9.8 ± 5.0 mmol/l (mean ± SEM), respectively.

After introduction of anesthesia the patient was placed in supine position with a rubber cushion under the left shoulder

Table 1
Pattern of coronary vessels grafted and used conduits[a]

Coronary lesions	Group 1 (53 patients)	Group 2 (69 patients)	Coronary vessels grafted and conduits used	Group 1 (53 patients)	Group 2 (69 patients)
LAD	48	69	LIMA → LAD	45	63
DB	17	27	LIMA FG → LAD	1	4
LCX	28	25	VG → LAD	1	1
IB	3	6	LIMA → LCX	1	0
RCA	20	25	RIMA → DB + LPLA	1	0
Main stem	8	6	RIMA → IB	0	1
			RAD → OM	1	0
			VG → DB	23	27
			VG → LCX	7	1
			VG → IB	3	5
			VG → OM	22	27
			VG → RCA	15	12
			Ostioplasty	0	1

[a] DB, diagonal branch of LAD; FG, free graft; IB, intermediate branch; LAD, left anterior descending coronary artery; LIMA (RIMA), left (right) internal mammary artery; LCX, left circumflex artery; OM, obtruse marginale branch of LCX; RAD, radial artery; RCA, right coronary artery; VG, vein graft.

with the left arm attached to the body dorsally to the posterior axial line.

A 6–9 cm skin incision at the level of the 3rd (seldom the 2nd) intercostal space (ICS) was made and the upper and the lower rib were divided at their sternal edge, but not removed. With a small wound retractor (Stortz Inc.) the LIMA was harvested as a pedicle up to the 1st rib and down to the 5th or 6th rib. In some cases further arterial conduits were harvested in addition. The pericardium was opened longitudinally. In parallel saphenous vein segments were harvested by another surgeon if necessary. In systemic heparinization, the right atrium was cannulated via the femoral vein. Cannulation of the ascending aorta was performed and a conventional aortic clamp was used for external cross clamping, all this through the same skin incision. Antegrade cold crystalloid cardioplegia was applied via the ascending aorta. During cardioplegic arrest aortic root venting was made and the relaxed heart was rotated for exposure of coronary arteries. End-to-side anastomoses were performed between vein grafts and the coronary arteries in a standard fashion followed by the anastomosis of the LIMA to LAD.

Antegrade de-airing was made via the ascending aorta and the aortic clamp was removed. While reperfusion proximal anastomoses were performed using a conventional side-biting clamp. The patient was weaned from CPB and cannulae were removed from the aorta and the femoral vein. Protamin was given, the pericardium was closed and the sternal edges of the 3rd and 4th rib were attached to the sternum using two steel wires. Both ribs were approximated to each other using a 1 mm diameter strong suture (Poly-*p*-dioxanon), two chest tubes were left in place and the chest incision was closed in layers.

2.3. Follow-up (both groups)

Duration of operation, LIMA harvesting time, duration of CPB, postoperative ventilation, intensive care unit (ICU) stay and hospitalization were monitored. Cardiac enzymes (CK/CKMB) were measured before operation, 6 h, and 2 days after surgery. Total volume of bleeding and blood units transfused were monitored in addition to hemoglobin and hematocrit values (Hb, Hk) on operative and postoperative day 1. X-ray evaluation was performed and the patients had a complete follow-up including physical examination, 12 led ECG and X-ray on postoperative day 2, 14, and 12 weeks after surgery. Back and wound pain assessment was performed on postoperative day 3. Apart from ECG, NYHA and CCS classification, stress ECG should complete the 3-month follow-up. Pathological stress ECG-findings were planned to be clarified with coronary angiogram.

3. Results

No death occurred in the whole series of both groups. All patients are alive at present and doing well up to 12 months postoperatively. All patients were weaned from CPB in sinus rhythm, without signs of ischemia or necessity for inotropic support. There was no perioperative infarction. CKMB/CK fraction was always normal. Forty-nine patients (92%) in group 1 and 67 patients in group 2 (93%) had a complete 3-month follow-up.

LIMA bypass to LAD and vein grafts or right internal mammary artery bypass to other coronary arteries if necessary were performed in all patients except six (11.3%) in group 1. Out of these patients one patient was referred for surgery due to a lesion of the strong diagonal branch. One patient had no available arterial conduits and further four patients were referred for surgery with the LAD not being amenable for surgery.

Left internal mammary artery bypass for LAD and vein grafts or right internal mammary artery bypass to other coronary arteries, if necessary, were performed in all patients, except one (1.4%) in group 2. In this old female patient lacking in arterial conduits, a vein graft was anastomosed to the LAD. In all patients of group 2, the procedure was completed as planned but in one case (1.4%). After having started the procedure through minithoracotomy in this patient we converted to median sternotomy, due to an undiagnosed heavily calcified ascending aorta, which was a serious exclusion criterion. This patient was excluded from the study and received conventional bypass surgery and had an uneventful postoperative course.

The pattern of the coronary vessels grafted and the used conduits of both groups are listed in Table 1.

Table 2
Perioperative data[a]

(Mean ± SEM)	Conventional technique (Group 1) $n = 53$	Dresden technique (Group 2) $n = 69$	Significance	Test
Time of operation (min)	162.9 ± 53.6	266.6 ± 61.7	$P < 0.01$	M–W-test
Time of LIMA-harvesting (min)	19.5 ± 7.0	43.6 ± 15.7	$P < 0.01$	M–W-test
Time of CPB (min)	65.4 ± 23.3	98.4 ± 34.7	$P < 0.01$	M–W-test
Time of cross-clamp (min)	36.3 ± 12.9	52.8 ± 21.0	$P < 0.01$	M–W-test
Time of postoperative ventilation (min)	303.8 ± 154.1	307.3 ± 144.2	N.S.	
ICU stay (days)	1.11 ± 0.47	1.07 ± 0.35	N.S.	
Hospital stay (days)	6.87 ± 5.88	7.45 ± 2.63	N.S.	

[a] CPB, cardiopulmonary bypass; ICU, intensive care unit; LIMA, left internal mammary artery; M–W-test, Mann–Whitney *U* test.

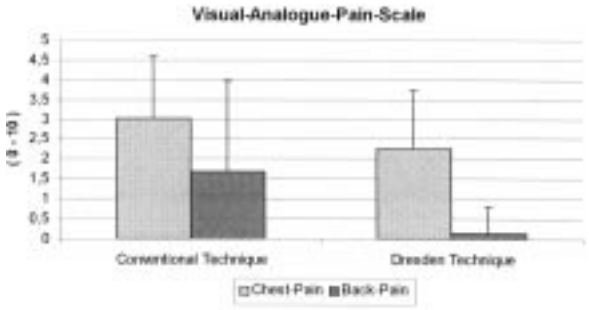

Fig. 1. Pain assessment – chest pain and back pain on postoperative day 3.

Duration of operation, duration of LIMA harvesting, CPB time, cross clamping time, ventilation, ICU stay and hospitalization of both procedures are listed in Table 2.

Bleeding volume 24 h after surgery, was 821.7 ± 387.0 ml (mean ± SEM) for group 1 and 549.6 ± 257.7 ml (mean ± SEM) for group 2, respectively ($P < 0.01$). Four hours after operation Hk and Hb were 30.5 ± 6.4% (mean ± SEM) and 7.2 ± 4.0 mmol/l (mean ± SEM) for group 1 and 32.5 ± 6.3% (mean ± SEM) and 7.4 ± 3.2 mmol/l (mean ± SEM) for group 2, respectively. The Hk value decreased postoperatively in comparison to the preoperative values to 71.3 ± 15.1% in group 1 and to 76.2 ± 12.5 in group 2 ($P < 0.05$ Mann–Whitney U test). Twenty-four patients (45.3%) in group 1 and 22 patients (31.9%) in group 2 required blood transfusion. Patients in group 1 received more blood units (1.51 ± 2.35) than patients in group 2 (0.68 ± 1.28) ($P < 0.05$ Mann–Whitney U test).

Pain assessment on postoperative day 3 using visual analog scale (VAS) pain scale revealed significantly less chest and back pain for group 2 as shown in Fig. 1 ($P < 0.05$ Mann–Whitney U test).

At time of discharge from hospital no patient of both groups showed any kind of arrhythmia, not known before operation. One patient (1.4%) of group 2 and two patients of group 1 (3.8%) were discharged with signs of ischemia in ECG from hospital.

3.1. Three-month follow-up

Two patients in each group had a pathological stress ECG at 3-month follow-up and received coronary angiography (3.8% for group 1 and 2.9% for group 2). Both patients of group 1 showed a stenosis of the LIMA-LAD anastomosis between 50 and 70% and both insisted on drug therapy. The first patient of group 2 showed a de-novo stenosis distally to the LIMA-LAD anastomosis and received an uneventful reoperation (1.4%). In the second patient a vein graft for the marginal branch of the circumflex artery was occluded. This patient was treated with drug therapy.

Clinical classification revealed in group 1, 44 (83%) patients at CCS stage 1, five (9%) patients at stage 2 and one (2%) patient at stage 3. In group 2, 63 (91.3%) patients were at CCS stage 1, three (4.2%) at stage 2 and three (4.2%) patients at stage 3. Thirty-five (66%) patients of group 1 were at NYHA class 1, 16 (30.1%) patients at class 2 and two (3.8%) at class 3. Forty-six patients (66.7%) of group 2 were at NYHA class 1, 23 (33.3%) patients at class 2.

3.2. Complications

One patient (1.9%) needed reexploration due to bleeding in group 1.

All patients of both groups were discharged from hospital without any chest wound infection from hospital except 1 patient (1.9 %) in group 1. Three patients (4.3%) from group 2 were discharged from hospital with delayed wound healing in the groin. These patients belong to our initial series as the groin was dissected for arterial and venous cannulation. As right atrium is cannulated percutaneous in the recent cases, this complication had never occurred again. Six weeks after operation there were two chest wound infections (3.7%) in group1 and three chest wound infections (4.3%) in group 2. This status did not change at the 3-month follow-up. There were two sternal instabilities (3.7) in group 1. Both patients received reoperation for sternal fixation. No thoracic cage instabilities occurred in group 2. In one patient (1.9%) of group 1 there was necessity of pacemaker implantation 6 weeks after operation.

4. Comment

Early reports about minimally invasive coronary artery bypass surgery (MICABS) [2,3,11], stimulated many surgical groups in working with such novel techniques [1,4,12,13]. Mack and colleagues presented excellent clinical and angiographic results, provided through MICABS [14], providing that 'key hole' surgery can safely be applied. The idea of performing coronary bypass surgery using CPB and cardioplegic arrest avoiding median sternotomy, was enforced from the Stanford group [1] and was first introduced in Europe by the Dresden group in an initial successful clinical trial [5]. In 'Port Access' procedures, a thorax herniation occurred and therefore the chest incision in made in the bed of the 4th rib with exarticulation of the cartilage of the rib. In the 3rd ICS and spreading the 3rd and the 4th ribs from each other, access to the ascending aorta can also be obtained, and therefore the complexity of the endovascular CPB system of Heartport is not necessary. If the ascending aorta is accessible then aortocoronary vein grafts can also be attached and the treatment of multivessel CAD under less invasive conditions is feasible [6].

Dresden technique (DT) enables percutaneous transfemoral right atrial cannulation and direct cannulation of the aorta, thus diminishing the danger of wound healing problems in the groin [5] on the one hand, and on the other hand, avoiding development of retrograde aortic dissections [10,15]. We initiated this clinical trial to prove that DT is, despite the learning curve, at least as good as the

conventional technique. The importance of this technique is emphasized, through patients who definitely benefit from a procedure avoiding median sternotomy, as patients with tracheostomas, invalid persons using walking sticks, etc. Precise preoperative evaluation of the patients allows a very low conversion rate (1.4%). Comparing DT to the conventional technique we found that the time of operation was longer in the DT group, but postoperative ventilation time, ICU stay, and hospitalization showed no significant difference. Small wound surface in DT is probably the reason, why patients in this group tend to bleed significantly less compared to patients receiving conventional surgery. This result was confirmed though significant lower hematokrit and hemoglobin values postoperatively in the conventional group. The efficacy of both techniques does not differ, as CCS and NYHA classification showed. Cardiac enzymes and stress ECG findings confirmed by angiography revealed good results in both groups comparable to those reported by other authors [16]. Less invasive access for coronary artery bypass surgery using the described technique is not combined with multiple wound healing problems. Reoperation due to sternum instability does not occur as in the conventional group, what also was the initial aim for developing this technique. Complete revascularization even in complex cases of coronary artery multivessel disease is enabled. Patients with serious risk factors for median sternotomy do really benefit from this procedure. Even in routine cases DT is attractive as postoperative pain is less, thus allowing an enhanced convalescence.

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